

## CLAIMS

What is claimed is:

1. A method of perforating a subterranean formation which is penetrated by a wellbore, the wellbore having casing cemented therein, a cement sheath around the casing, so as to establish fluid communication between the formation and the wellbore, the method comprising the steps of:  
perforating the casing using a mechanical perforator; and thereafter  
igniting a propellant material disposed in the perforated casing  
thereby perforating the cement sheath.
2. A method as in 1 further comprising the step of stimulating the formation with an acid stimulator.
3. A method as in 1 wherein the step of perforating the casing using a mechanical perforator further includes perforating at least some distance into the cement sheath.
4. A method as in 1 wherein the mechanical perforator comprises at least one toothed wheel.
5. A method as in 4 wherein the at least one toothed wheel included extendable teeth.
6. A method as in 1 wherein the mechanical perforator comprises needle-punch perforator.
7. A method as in 1 wherein the propellant material comprises a propellant stick.

- 1 8. A method as in 1 wherein the propellant material comprises a  
2 propellant sleeve.  
3
- 4 9. A method as in 1 wherein the step of igniting the propellant material  
5 further comprises expelling an abrasive material through the perforations in  
6 the casing thereby scouring the perforations in the cement sheath.  
7
- 8 10. A method as in 1 wherein the propellant further acts in part to  
9 perforate the formation.  
10
- 11 11. A method as in 9 wherein the abrasive material acts in part to  
12 perforate the formation.  
13
- 14 12. A method as in 1 further comprising the step of deploying in the  
15 casing a perforator subassembly including the mechanical perforator.  
16
- 17 13. A method as in 12 wherein the mechanical perforator includes at  
18 least one toothed wheel.  
19
- 20 14. A method as in 1 further comprising the step of deploying in the  
21 casing a propellant subassembly including the propellant material.  
22
- 23 15. A method as in 14 wherein the propellant subassembly further  
24 comprises an abrasive material.  
25
- 26 16. A method as in 15 wherein the step of igniting the propellant  
27 material further comprises expelling the abrasive material through the  
28 perforations in the casing.  
29

1 17. A method as in 2 further comprising the step of deploying in the  
2 casing an acid stimulation subassembly for delivery of the acid stimulator to  
3 the formation.

4  
5 18. A method as in 1 wherein the casing is expandable casing.

6  
7 19. An apparatus for perforating a subterranean formation which is  
8 penetrated by a wellbore, so as to establish fluid communication between the  
9 formation and the wellbore, the wellbore having casing cemented therein, a  
10 cement sheath around the casing, the apparatus comprising:

11 a mechanical perforator subassembly for creating perforations at  
12 least in the casing; and

13 a propellant subassembly for creating perforations in at least the  
14 cement sheath.

15  
16 20. An apparatus as in 19 further comprising an acid stimulation  
17 subassembly for delivery of the acid stimulator to the formation.

18  
19 21. An apparatus as in 19 wherein the mechanical perforator capable  
20 of perforating at least some distance into the cement sheath.

21  
22 22. An apparatus as in 19 wherein the mechanical perforator  
23 subassembly comprises at least one toothed wheel.

24  
25 23. An apparatus as in 22 wherein the at least one toothed wheel  
26 includes extendable teeth.

27  
28 24. An apparatus as in 19 wherein the mechanical perforator  
29 subassembly comprises a needle-punch perforator.

1 25. An apparatus as in 19 wherein the propellant subassembly  
2 comprises a propellant stick.

3  
4 26. An apparatus as in 19 wherein the propellant subassembly  
5 comprises a propellant sleeve.

6  
7 27. An apparatus as in 19 wherein the propellant subassembly  
8 comprises propellant and an abrasive material for expulsion through the  
9 perforations in the casing created by the mechanical perforation assembly.

10  
11 28. An apparatus as in 19 wherein the propellant subassembly is  
12 further capable of creating perforations in the formation.

13  
14 29. An apparatus as in 27 wherein the abrasive material is capable of  
15 perforating the formation.

16  
17 30. An apparatus as in 19 wherein the casing is expandable casing.

18  
19 31. A method of perforating a subterranean formation which is  
20 penetrated by a wellbore, so as to establish fluid communication between the  
21 formation and the wellbore, the method comprising the steps of:  
22 cementing casing in the wellbore thereby creating a cement sheath  
23 around at least a portion of the casings  
24 perforating the casing using a mechanical perforator; and thereafter  
25 igniting a propellant material disposed in the perforated casing.

26  
27 32. A method as in 31 wherein the step of cementing casing further  
28 comprises expanding the casing.

1 33. A method as in 31 further comprising the step of stimulating the  
2 formation with an acid stimulator.

3  
4 34. Method as in 31 wherein the step of perforating the casing using a  
5 mechanical perforator further includes perforating at least some distance into  
6 the cement sheath.

7  
8 35. A method as in 31 wherein the mechanical perforator comprises at  
9 least one toothed wheel.

10  
11 36. A method as in 31 wherein the mechanical perforator comprises a  
12 needle-punch perforator.

13  
14 37. A method as in 31 wherein the propellant material comprises a  
15 propellant sleeve.

16  
17 38. A method as in 31 wherein the step of igniting the propellant  
18 material further comprises expelling an abrasive material through the  
19 perforations in the casing.

20  
21 39. A method as in 32 further comprising the step of stimulating the  
22 formation with an acid stimulator.

23  
24 40. A method as in 32 wherein the step of perforating the casing using  
25 a mechanical perforator includes perforating at least some distance into the  
26 cement sheath.

1        41.        A casing perforator apparatus for perforating casing disposed in a  
2        wellbore, the apparatus comprising:  
3                a perforator body; and  
4                a plurality of toothed wheels movably mounted to the perforator  
5        body.

6  
7        42.        An apparatus as in 41 the casing perforator having three toothed  
8        wheels, each wheel having a different axis of rotation.

9  
10       43.        An apparatus as in 41 wherein at least one of the toothed wheels  
11       has extendable teeth.

12  
13       44.        An apparatus as in 41 further comprising means for moving the  
14       toothed wheels into contact with the casing.

15  
16       45.        An apparatus as in 41 wherein the casing is cemented in the  
17       wellbore, having a cement sheath around the casing.

18  
19       46.        An apparatus as in 45 wherein the plurality of toothed wheels have  
20       teeth capable of perforating at least some distance into the cement sheath.

21  
22       47.        A casing perforator apparatus for perforating casing disposed in a  
23       wellbore, the apparatus comprising:  
24                a perforator body;  
25                and at least one toothed wheel movably mounted to the body, each  
26       wheel having a plurality of extendable teeth movable between a retracted  
27       position and an extended position.

28  
29       48.        An apparatus as in 47 the at least one toothed wheel comprising  
30       three toothed wheels.

1 49. An apparatus as in 47, each toothed wheel having an actuator for  
2 moving the teeth to the extended position.  
3

4 50. An apparatus as in 49, each toothed wheel having a locking  
5 mechanism for at least temporarily locking the teeth in the extended  
6 position...

7 51. A casing perforator apparatus for perforating casing disposed in a  
8 wellbore, the apparatus comprising:

9 a perforator body; and

10 a plurality of perforator needles movable between a retracted  
11 position and an extended position; and

12 an actuating means for moving the needles from the retracted  
13 position to the extended position.  
14

15 52. An apparatus as in 51 the actuating means capable of moving the  
16 needles from the extended position to the retracted position.  
17

18 53. An apparatus as in 51 wherein the needles are shearable from the  
19 perforator body.  
20

21 54. An apparatus as in 51 wherein the needles are mounted in a  
22 generally radial position when in the retracted position.  
23

24 55. An apparatus as in 53 wherein the needles are soluble in acid  
25 solution.  
26

27 56. An apparatus as in 51 wherein the actuating means is a  
28 substantially conical expansion plug  
29 .

1 57. An apparatus as in 51 wherein the casing is cemented in the  
2 wellbore a cement sheath around the casing.

3  
4 58. An apparatus as in 57 wherein the needles are capable of  
5 perforating through the casing and at least some distance into the cement  
6 sheath.

7  
8 59. A method of perforating a casing in a wellbore, the method  
9 comprising:

10 positioning a perforator in the casing, the perforator having a  
11 plurality of perforator needles movable mounted thereon, the needles in a  
12 retracted position; and

13 moving the needles to an extended position and perforating the  
14 casing with the needles.

15  
16 60. A method as in 59 further comprising the step of moving the  
17 needles from the extended position to the retracted position.

18  
19 61. A method as in 59 further comprising the steps of disconnecting the  
20 needles from the perforator.

21  
22 62. A method as in 61 further comprising dissolving the needles.

23  
24 63. A method as in 59 wherein the step of moving the needles includes  
25 moving an extension plug through the perforator.

26  
27 64. A method as in 59 wherein the casing is cemented in the wellbore,  
28 a cement sheath around the casing, and further comprising the step of  
29 perforating at least some distance into the cement sheath.



1 65. A well casing apparatus for a subterranean formation which is  
2 penetrated by a wellbore, the casing comprising:  
3 a substantially tubular casing having a casing wall with a plurality of  
4 perforations therethrough; and  
5 a plurality of sacrificial plugs secured to the casing wall and sealing  
6 the plurality of perforations.

7  
8 66. An apparatus as in 65 wherein the casing and plugs are  
9 expandable, such that the plugs remain secured to the casing wall, sealing  
10 the plurality of perforations, when the casing is expanded.

11  
12 67. An apparatus as in 65 wherein the sacrificial plugs are soluble in an  
13 acid or caustic solution.

14  
15 68. An apparatus as in 67 wherein the plugs comprise aluminum.

16  
17 69. An apparatus as in 66 wherein the sacrificial plugs are soluble in an  
18 acid or caustic solution.

19  
20 70. An apparatus as in 69 wherein the plugs comprise aluminum.

21  
22 71. An apparatus as in 66 wherein the sacrificial plugs are shearable.

23  
24 72. An apparatus as in 71, the casing wall enclosing a casing bore, and  
25 wherein each plug has a body portion engaging the casing wall and having a  
26 stub portion projecting into the casing bore, the body portion intersected by a  
27 relief pocket.

28  
29 73. As in 65 wherein the sacrificial plugs further comprise a wellbore  
30 protrusion projecting into the wellbore.

1        74.        An apparatus as in 66 wherein the sacrificial plugs further comprise  
2 a wellbore protrusion projecting into the wellbore.

3  
4        75.        An apparatus as in 74 wherein the plug protrusions comprise  
5 EPDM.

6  
7        76.        An apparatus as in 65 wherein the sacrificial plugs comprise  
8 reactive plugs.

9  
10       77.        An apparatus as in 14 wherein the reactive plugs are mounted to  
11 the casing wall in preformed recesses therein.

12  
13       78.        An apparatus as in 76 wherein the reactive plugs comprise an  
14 elastomer.

15  
16       79.        An apparatus as in 81 wherein the reactive plugs expand in a  
17 prescribed geometric pattern in the presence of a pre-selected additive.

18  
19       80.        An apparatus as in 79 wherein the reactive plugs expand in the  
20 presence of diesel.

21  
22       81.        An apparatus as in 66 wherein the sacrificial plugs comprise  
23 reactive plugs.

24

1 82. An apparatus as in 81 wherein the reactive plugs are mounted to  
2 the casing wall in preformed recesses.

3  
4 83. An apparatus as in 81 wherein the reactive plugs are mounted to  
5 the casing wall in preformed recesses.

6  
7 84. An apparatus as in 81 wherein the reactive plugs expand in a  
8 prescribed geometric pattern in the presence of a pre-selected additive.

9  
10 85. An apparatus as in 84 wherein the reactive plugs expand in the  
11 presence of diesel.

12  
13 86. An apparatus as in 76 wherein the reactive plugs dissolve in an  
14 acid or caustic solution.

15  
16 87. An apparatus as in 81 wherein the reactive plugs dissolve in an  
17 acid or caustic solution.

18  
19 88. A method of completing a well having a wellbore penetrating a  
20 subterranean formation, the method comprising the steps of:  
21 placing a substantially tubular casing having a casing wall  
22 enclosing a casing bore, the casing wall having a plurality of sacrificial plugs  
23 secured to the casing wall and sealing the plurality of perforations; and  
24 rupturing the sacrificial plugs, thereby establishing fluid  
25 communication between the wellbore and the casing bore.

26  
27 89. A method as in 88 further comprising the step of expanding the  
28 casing and sacrificial plugs such that the plugs remain secured to the casing  
29 wall and sealing the plurality of perforations during expansion of the casing  
30 and plugs.

1 90. A method as in 89 further comprising the step of cementing the  
2 casing in the wellbore.

3  
4 91. A method as in 88 wherein the step of rupturing the plugs further  
5 comprises dissolving the plugs.

6  
7 92. A method as in 91 wherein the plugs are dissolved in an acid  
8 solution.

9  
10 93. A method as in 91 wherein the plugs comprise aluminum.

11  
12 94. A method as in 89 wherein the step of rupturing the plugs further  
13 comprises dissolving the plugs.

14  
15 95. A method as in 89 wherein the step of rupturing the plugs  
16 comprises shearing a portion of the plugs.

17  
18 96. A method as in 95 wherein the plugs each comprise a body portion  
19 secured to the casing wall and stab portion projecting in to the casing bore,  
20 the body portion intersected by a relief pocket.

21  
22 97. A method as in 95 wherein the plugs each comprise a protrusion  
23 extending into the wellbore.

24  
25 98. A method as in 90 the step of cementing creating a cemented  
26 sheath around the casing, and wherein the plugs comprise protrusions  
27 projecting into the wellbore and into the cement sheath.

1 99. A method as in 90 wherein the plugs are reactive plugs and further  
2 comprising the step of expanding the reactive plugs such that a protruding  
3 portion of each of the plugs projects into the wellbore and into the cement.  
4

5 100. A method as in 99 wherein the reactive plugs expand in the  
6 presence of a preselected additive.  
7

8 101. A method as in 100 wherein the step of cementing further  
9 comprises the step of placing the additive into the wellbore adjacent the plugs  
10 in the casing.  
11

12 102. A method as in 101 wherein the reactive plugs are an elastomer  
13 and the additive is diesel.  
14

15 103. A method as in 99 further comprising the step of dissolving the  
16 reactive plugs after the step of expanding the reactive plugs.  
17

18 104. A method as in 88 further comprising the step of cementing the  
19 casing in the wellbore.  
20

21 105. A method as in 104 wherein the plugs are reactive plugs and  
22 further comprising the step of expanding the reactive plugs such that a  
23 protruding portion of each of the plugs projects into the wellbore and into the  
24 cement.  
25

26 106. A method as in 105 wherein the reactive plugs expand in the  
27 presence of a preselected additive.  
28

1 107. A method as in 105 wherein the step of cementing further  
2 comprises the step of placing the additive into the wellbore adjacent the plugs  
3 in the casing.  
4

5 108. A method as in 107 wherein the reactive plugs are an elastomer  
6 and the additive is diesel.  
7

8 109. A method as in 105 wherein the plugs are reactive plugs and  
9 further comprising the step of expanding the reactive plugs such that a  
10 protruding portion of each of the plugs projects into the wellbore and into the  
11 cement.  
12

13 110. An apparatus for completing a well in a subterranean  
14 formation penetrated by a wellbore, the apparatus comprising:  
15 a casing having a casing wall;  
16 a plurality of perforations through the casing wall;  
17 a plurality of plugs corresponding to the plurality of perforations, the  
18 plugs sealing the plurality of perforations; and  
19 a plurality of extendable fingers secured to the casing wall adjacent  
20 the plurality of the perforations, each of the fingers movable between a run-in  
21 position wherein the fingers do not interfere with the casing being run-in to the  
22 wellbore, and an extended position wherein the fingers project radially from  
23 the casing wall.  
24

25 111. An apparatus as in 110 wherein the casing is expandable.  
26

27 112. An apparatus as in 111 wherein each of the fingers is  
28 movable between the extended position and a final position wherein each  
29 finger pierces a corresponding plug.

1 113. An apparatus as in 111 wherein each finger comprises an  
2 explosive charge for perforating the subterranean formation.  
3

4 114. An apparatus as in 110, the casing wall enclosing a casing  
5 bore, and further comprising a propellant subassembly in the casing bore  
6 ignitable to vacate the casing bore through the plurality of perforations.  
7

8 115. The apparatus as in 110, wherein each finger is pivotally  
9 attached to the casing wall.  
10

11 116. The apparatus as in 110, wherein a wire extends from each  
12 finger, the wire for engaging the wellbore and moving the finger between the  
13 run-in and the extended positions.  
14

15 117. The apparatus as in 110, the fingers movable between the  
16 run-in and extended positions by a spring device.  
17

18 118. The apparatus as in 117, wherein the spring device is a  
19 torsion spring device.

1  
2 119. A method of perforating a subterranean formation which is  
3 penetrated by a wellbore, so as to establish fluid communication between the  
4 formation and the wellbore, the method comprising the steps of:

5 running a casing into the wellbore, the casing having a casing wall,  
6 a plurality of perforations through the casing wall, a plurality of plugs sealing  
7 the plurality of perforations, and a plurality of fingers secured to the casing  
8 wall adjacent the plurality of perforations, the fingers in a run-in position  
9 wherein the fingers do not interfere with running the casing into the wellbore;

10 moving each of the plurality of fingers to an extended position  
11 wherein each finger projects radially outward from the casing wall; and  
12 thereafter

13 igniting a propellant, the propellant exiting through the plurality of  
14 perforations and the plurality of fingers thereby perforating the formation.  
15

16 120. A method as in 119 further comprising the step of  
17 expanding the casing.  
18

19 121. method as in 119 wherein the propellant is mounted in the plurality  
20 of fingers.  
21

22 122. A method as in 119 wherein the propellant is disposed in the  
23 casing.  
24

25 123. A method as in 122 further comprising the step of running a  
26 propellant subassembly into the casing.  
27

28 124. A method as in 119 further comprising the step of cementing the  
29 casing in the wellbore.



1 125. A method as in 124 further comprising the steps of expanding the  
2 casing.

3  
4 126. A method as in 119 further comprising the step of moving each of  
5 the plurality of fingers from the extended position to a final position wherein  
6 each of the fingers pierces a corresponding plug.

7  
8 127. A method as in 126, the step of moving the fingers to a final  
9 position further comprising expanding the casing such that the fingers contact  
10 the wellbore wall.

11  
12 128. A method as in 119 wherein each finger is pivotally attached to the  
13 casing wall.

14  
15 129. A method as in 119 wherein a wire extends from each finger, the  
16 wire for engaging the wellbore and moving the finger between the run-in and  
17 the extended positions.

18  
19 130. A method as in 119 the fingers movable between the run-in and  
20 extended positions by a spring device.

21  
22 131. A method as in 130 wherein the spring device is a torsion spring  
23 device.